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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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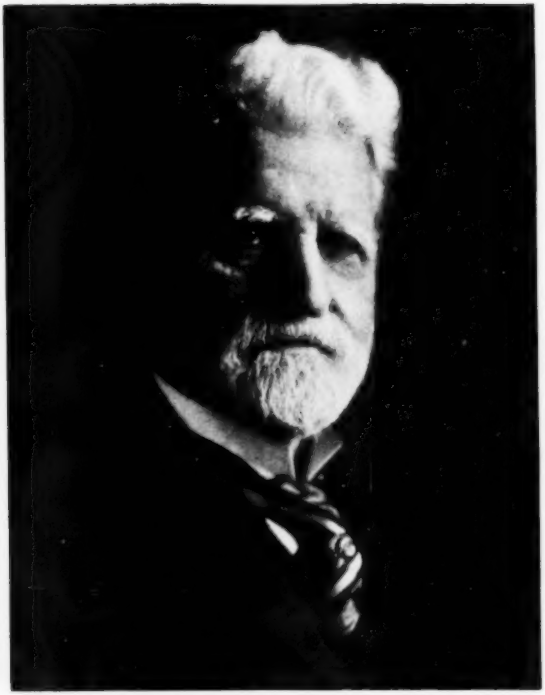

Ambrose Swasey, 1846-1937.

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AMBROSE SWASEY

Engineer, Scientist, Philanthropist

By J. S. PLASKETT

(*With plate X*)

AMBROSE SWASEY was born at Exeter, New Hampshire, from one of New England's earliest families, on December 19, 1846 and died at the old homestead near Exeter, after a long, useful, and happy life, on June 15, 1937, at the age of 90½ years. While his formal education was confined to the elementary school at Exeter, his remarkable career is indisputable evidence that his real education continued throughout his life. Endowed with simplicity and nobility of character, with a sound body and brilliant mind and with a true sense of artistic values, along with mechanical ability of the highest order—a remarkable combination—it is not surprising that he earned the respect and affection of all who were privileged to know him and that few men have left a wider circle of warm friends. Neither is it surprising that he was awarded the highest honours in the gift of his fellow countrymen for his mechanical and scientific achievements and for his many benefactions to scientific, educational and religious organizations.

In 1865, in his nineteenth year, he entered on a three-year apprenticeship in the general machine shop in Exeter, where, a year later he was joined by Worcester Reed Warner. The two apprentices boarded together and became warm and lifelong friends, this association subsequently developing into the world-famous firm of Warner & Swasey. While Mr. Warner was completing his appren-

ticeship, Mr. Swasey worked for three months in a locomotive shop in Patterson, N.J., but, not liking this work, returned to the Exeter shop until Mr. Warner also became a "journeyman". The two friends started out to "make their fortune", journeying to Hartford, Conn., May 24, 1869, where, after a two weeks' trial of engine building, apparently an insufficient test of their skill, they moved to the Pratt & Whitney Company, famous as builders of high grade machine tools, where they remained for eleven years, continually developing their ingenuity and skill.

Mr. Swasey was soon placed in charge of the gear cutting department where his mechanical genius rapidly developed improvements in the methods of making fine gears, eventually leading to the first method of generating and cutting epicycloidal teeth by a purely mechanical process. His first patent, on improvements in protractors, was granted in 1875, followed in later years by numerous other patents on turret operating mechanism and other improvements in machine tools, and on optical sighting devices and range finders.

The two friends left the Pratt & Whitney Company in 1880 and started a machine tool business in Chicago. Finding after a year, however, that the major manufacturing operations and the sources of supplies and of skilled labour were considerably nearer the Atlantic Seaboard, they moved to their present location in Cleveland. Their great success in building turret lathes and other high grade machine tools required almost continuous increase in their manufacturing facilities. Finally, in 1906 when their shop was enlarged to three times its former size, the partners decided to resist further expansion, in order that they might have, as Mr. Swasey put it "Time to travel, to look about us, to pass some time with our friends, and to enjoy the good things of life." This very wise decision was followed, but with such a sense of balance and fitness, and with such helpfulness to worthy enterprises, and to their friends and associates as rounded their outlook and brought greater richness into their lives.

An astronomical journal is hardly the place to enlarge further on a world-famous machine tool business or to catalogue the numerous contributions made by the ingenuity and skill in design of Mr. Swasey in their tool business and in the construction of scientific instruments

of the highest precision such as range finders, meridian instruments, etc., in which they soon became engaged. For the accurate graduation of the circles required on these instruments, Mr. Swasey designed and had constructed a circular dividing engine based on engineering principles rather than on the instrument tradition of previous engines. It seems obvious that the genius of Mr. Swasey, the great interest of Mr. Warner in astronomy, and the splendid facilities of their organization for constructing tools and instruments of the highest precision formed an unequalled combination for the mounting of astronomical telescopes. This was especially true at this time when the rapidly increasing size of telescopes made it imperative that engineering methods rather than instrument making practice should be applied to the mountings.

The first Warner & Swasey telescope was built in 1881 for Beloit College, Beloit, Wisconsin; in 1882 a dome was made for Leander McCormick Observatory in Virginia. It was not, however, until 1885-6 that the first great test of Mr. Swasey's skill in telescope design came when the firm was invited to submit designs and tenders for the mounting of a 36-inch telescope for the Lick Observatory on Mount Hamilton, California. On May 29, 1886, Mr. Warner telegraphed Mr. Swasey that they had been awarded the contract for the mounting of the 36-inch telescope. Bids had been invited from another firm in America and from one firm each in Ireland, France and Germany. Although the bid of Warner & Swasey, the firm with the least experience in telescope building, and practically unknown in either Europe or America, was found to be considerably higher than the others, the design was considered so superior by the trustees that the contract was unanimously awarded to Warner & Swasey.

Construction proceeded rapidly and in November, 1887, Mr. Swasey travelled to Mount Hamilton to superintend the erection of the mounting on its foundation within the already completed dome. The 36-inch objective, made by Alvan Clark & Sons, was installed in the tube on December 31, 1887, and on the next clear night, January 3, 1888, the instrument was first tested. Mr. Swasey has told with considerable amusement that the focal length of the objective was six inches shorter than specified and that Alvan Clark Junior

who had figured it was much perturbed, enlarging on the difficulty and danger of changing it, and protesting that it would practically mean doing his work all over again. Mr. Swasey's kindliness soon overcame his love of joking and he relieved Mr. Clark's anxiety by assuring him it could be remedied much more easily and proceeded next morning to cut off six inches of the tube with a hack saw and refit the breech block. On the next fine night, January 7, the telescope was again tested before Captain Floyd, the chairman of the Lick Trust, Mr. Swasey, Mr. Clark, and Prof. Keeler, the latter expressing himself as highly delighted with the performance of the instrument. The astronomical work done by this great telescope soon made it and the Lick Observatory famous and firmly established the reputation of Warner & Swasey as telescope builders par excellence and of Mr. Swasey as designer.

The next great telescope of Mr. Swasey's design was the 40-inch Yerkes refractor, the largest in the world, which was completed in 1897, the contract including also the dome and rising floor. The lines of this mounting followed generally those of the Lick Telescope, with improvements suggested by experience. This instrument has also been successful although the poorer astronomical climate in Wisconsin and the superior quality of the 36-inch objective have made the Yerkes less efficient than the Lick telescope. These two great refractors, the largest in the world, were, to a greater extent than the later telescopes, peculiarly Mr. Swasey's own design in both form and mechanism, and mark a great advance not only in accuracy and mechanical performance but in beauty and harmony of line. All of Mr. Swasey's designs, whether of machine tools, scientific instruments, or telescope mountings were characterized on the one hand by the simplest possible mechanism to achieve the desired purpose, by absence of purposeless ornamentation, by suitable strength and ruggedness where required, and on the other hand by smoothly flowing, pleasing line and harmony and beauty of form. Mr. Swasey was unequalled in combining engineering requirements with a real artistic sense of symmetry and proportion.

Besides a number of smaller refractors, the 26-inch Clark objective of the Naval Observatory, Washington, was completely re-

mounted and equipped with a rising floor and new dome. This was the last of the large refractors of Warner and Swasey, as, with the change of emphasis from visual to photographic observations, with the great loss of light by absorption as the size and thickness increased, and with the great difficulties in making discs larger than 40 inches, the reflector became much more efficient than the refractor. Furthermore, the great success of the Mount Wilson 60-inch reflector convincingly demonstrated the superiority of reflectors in modern astronomical work.

Although work had been commenced on a 60-inch fork-type reflector for the Argentine National Observatory, the first large reflecting telescope constructed by The Warner & Swasey Company was a 72-inch with dome and accessories for the Canadian Government, erected near Victoria, B.C. The general form of the mounting and some original features, such as the exclusive use of ball bearings on polar and declination axes, were laid down in the specifications, but the constructional and operating mechanism were designed by Mr. E. P. Burrell, Works Engineer of the Company, whose untimely death preceded that of Mr. Swasey by only four months. The beautiful lines of this mounting, unequalled in either earlier or later telescopes and the symmetry and harmony of the design were due to the engineering artistry of Mr. Swasey, who possessed a real genius in harmonizing the mechanical design with the beautiful and satisfying in appearance. This telescope set a new standard in accuracy, convenience and speed of operation, amply confirmed by the quality and quantity of the work produced in its twenty years of operation.

The 60-inch Argentine reflector, previously mentioned, was completed in 1922 and a 69-inch reflecting telescope with dome for the Ohio Wesleyan University at Delaware, Ohio, in 1923. The former was of the fork type along lines specified by Perrine, but the latter was similar to the 72-inch, although hardly as well proportioned as such direct control over the general design of this and subsequent telescopes was not exercised by Mr. Swasey. There is now approaching completion for the McDonald Observatory of the University of Texas an 82-inch reflecting telescope, the largest and most advanced telescope yet constructed by The Warner & Swasey Company. The contract calls for the complete equipment and consists of the mount-

ing and operating accessories, the 82-inch mirror and other optical parts, and the building and dome to house the instrument. This telescope has many original and valuable features and is a masterpiece of mechanical design due to the genius of Mr. Burrell. Although Mr. Swasey exercised general supervision over the design of this and the Argentine and Delaware telescopes, he did not take so active an interest as in the 72-inch telescope, probably the finest example of his artistry.

Before passing to other aspects of his career, one characteristic remark of Mr. Swasey, who undoubtedly had much greater interest and enjoyment, latterly, in building telescopes than manufacturing machine tools, may be quoted as illustrating the combination of idealism and business instinct in his character. "We have never made money out of telescopes, but the money we have put in that end of our business has brought us invaluable returns in the form of contacts which have helped in the production and sale of turret lathes to which we look for profit."

The engineering genius and the architectural and artistic ability of Mr. Swasey do not begin to cover his claims to fame and to the admiration and affection of his fellows. His friends, and they were legion, for he made friends wherever he went, will rather remember him for his sterling integrity, his kindly and generous spirit, his keen sense of humour, a constant delight to his friends, and for his philanthropy as manifested in unnumbered benefactions for scientific, educational, charitable, and religious purposes. Indeed, he gave away during his lifetime the major part of his well-earned wealth in accordance with his carefully made plan of earlier life.

It was only natural that a man of Mr. Swasey's genius should join the American Society of Mechanical Engineers in the year of its founding, and that he should find in this Society ample opportunity to develop his remarkable faculty of making warm and lifelong friends, especially among men of his own interests and ideals. As the years passed, his qualities of leadership and engineering ability brought him to the forefront of the Society, which never tired of doing him honour, while he never tired of helping them directly by his services and gifts and indirectly by his rapidly growing fame. He took an active part in the construction of the Engineering Building

for the Engineering Societies and was influential in persuading Mr. Carnegie to make the gift of this building. He served as President of the American Society of Mechanical Engineers in 1904 and was made an honorary member in 1916. In 1924 the Founder Societies awarded him their highest honour, the John Fritz Medal. He was awarded the Franklin Gold Medal in 1932 and became A.S.M.E. Medalist in 1933. The Society, in 1936, about the time of his ninetieth birthday and in the presence of the first recipient, Herbert Hoover, made him the only other recipient of the Hoover Gold Medal.

Numerous academic honours and other distinctions have been given to Mr. or Dr. Swasey. He received the degree of Doctor of Engineering from Case School of Applied Science in 1905, and of Doctor of Science from Denison University in 1910, from the University of Pennsylvania in 1924 and from Brown University in 1931. The honorary degree of Doctor of Laws was awarded to Dr. Swasey by the University of California in 1924, of Rochester in 1925, and of New Hampshire in 1930. The Government of France conferred on him the distinction of Chevalier of the Legion of Honour in 1901 and of Officer of the Legion of Honour in 1921. Dr. Swasey was proud of these last distinctions and always wore the insignia, a small red button in his coat lapel. He was elected to membership in the National Academy in 1922, in the American Philosophical Society a little later and rarely missed meetings of these two Societies, attending the April meeting of the National Academy in Washington less than two months before his death.

Dr. Ambrose Swasey's list of honours is rivalled, indeed exceeded, by the list of his benefactions to his church and other religious organizations, to education, to engineering and science, and to the poor. Dr. Swasey was a lifelong adherent and supporter of the Baptist Church and it was related in the funeral oration that his first experience of giving was to go out into the woods with his brother, chop a couple of cords of wood and haul it to the Baptist Parsonage where Rev. Noah Hooper lived. It was this same minister who baptized him in 1864 and married him in 1871. To the Baptist Church at Exeter and the First Baptist Church in Cleveland, he was a constant source of strength in service and benefactions, as also to other Baptist organizations.

Dr. Swasey gave liberally to educational institutions, generally in the form of buildings, as was natural in view of his interest in art and architecture. He endowed a Professorship in Applied Physics in the Case School of Applied Science, held by his friend, Dayton C. Miller, and with Mr. Warner presented to the same institution a finely equipped observatory. Dr. Swasey gave a Chapel and an Observatory to Denison University, a library building to the Colgate-Rochester Divinity School, a Christian Association Building for the Canton Christian College (now Lingnan University), and a Science Building for the University of Nanking. Many of his benefactions are unknown, but perhaps the most outstanding is the gift of $750,000 to establish the Engineering Foundation for the specifically stated purpose "For the furtherance of research in engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind." There are in addition unrecorded gifts to institutions and individuals which only they gratefully know and recall.

Dr. Swasey was married in 1871 to Lavinia Dearborn Cummings who died in 1913. There are no children to survive him and carry on his name, but his memory will be kept alive by the great engineering and scientific products due to his genius and industry, and by the organizations and causes aided by his philanthropy. Above all, the memory of a noble character and of a true and lovable gentleman will be dearly cherished by those who had the privilege of knowing him. This sketch of his career cannot be more fitly closed than by a quotation from a citation by Philip Fox on the occasion of the presentation of the Washington Award in 1935—"Dweller on earth for many years; great in engineering achievements, in production and administration; great in ingenuity and accomplishment; great in breadth of view; great in simplicity and forthrightness; great in sympathies and spirituality; great in appreciation of the essentials and obligations of life; maker of machines, institutions and men; a very noble gentleman, an engineer worthy to stand in the Washington succession; a worker with helping hand outstretched and heart aglow for his fellowmen. I am persuaded that as he walked the earth among us, he walked with eyes uplifted to the eternal stars."

Victoria, B.C.

KEPLER AND THE STAR OF BETHLEHEM

By W. Burke-Gaffney, S.J.

The purpose of this article is to consider the questions:

1. How did Kepler come to write about the Star of Bethlehem?
2. What conclusion did he come to about it?
3. Who was the first to suppose that it might have been merely a conjunction of planets?
4. By whom was this hypothesis first attributed to Kepler?
5. Were there planets so close in 7 or 6 B.C. that they could be mistaken for a single star?

The astrologers of old observed that Jupiter was in conjunction with Saturn about every twenty years. They calculated that this conjunction took place in the same part of the sky every eight hundred years. In December 1603 there was to be a conjunction of Jupiter with Saturn in Sagittarius, which, to the astrologers was one of the points of the Fiery Trigon. In the autumn of 1604, when Jupiter and Saturn were still in the Fiery Trigon, and not far apart, Mars was to come, and be in conjunction with Saturn on September 26, and with Jupiter on October 9. Thus, in early October 1604 Mars, Jupiter and Saturn would be at the vertices of a triangle,—forming a fiery triangle in the Fiery Trigon. A conjunction in the Fiery Trigon presaged great things; a fiery triangle there was surpassed, as an omen, only by a comet. Indeed, there were some who held that a comet was foreboded by the triangle of fire in the Fiery Trigon. I say "some", for by 1603 Germany was flooded with the predictions of astrologers for the following year.

The prelude to the great event, the conjunction of December 1603, was not spectacular. The planets were too close to the sun. They rose less than an hour before it. Kepler had predicted the conjunction for "between December 16 and 18". On the morning of the 16th he was at his post. Jupiter rose after dawn. Kepler could not see Saturn, the light of day was too bright. On the 17th it rained, at Prague; and not until Christmas morn was there a cloudless sky. On the morning of the 25th Kepler saw Jupiter, Saturn and Mer-

cury, forming, as it were, a triangle in the sky. From his observations of December 16 and 25 he calculated that the conjunction of Jupiter and Saturn took place at mid-day December 17. He also calculated that Mercury was in conjunction with Saturn, December 22, and with Jupiter, December 23. He calculated that at the conjunction of December 17 Jupiter was 1° 5′ vertically above Saturn, that is about twice the diameter of the moon above Saturn.

In the following September all eyes were turned to the sky; "some" says Kepler "watched, to correct their ephemerides, some, for the sake of pleasure, some, because of the rarity of the occasion, some, to verify their predictions, and others, indeed, to see if there would be a comet, as had been expressly predicted by the astrology of the Arabs".[1] The planets were well placed for observation, setting about five hours after the sun. Saturn was about 7 degrees west of Jupiter. On September 26 Mars was in conjunction with Saturn. Kepler's luck was as before; it was cloudy at Prague. On the following evening, however, he saw the planets, and measured their positions. His observations showed Mars to be 3° lower than Saturn. Mars was in conjunction with Jupiter on October 9. Kepler calculated that at the time of conjunction Mars was 2° below Jupiter. He did not see the planets at all on the evening of the 9th, for the reason that it was cloudy again. He had last observed them himself on October 3. His assistant made observations on October 7. One Johann Brunowsky, assistant to the Imperial Vice-Chancellor, saw them, from Prague, October 8, "through a rift in the clouds". There were no rifts in the clouds over Prague on the evening of the 9th. But that evening Fabricius in Switzerland, Maestlin at Tübingen, and Roeslin in Alsace, observed them, and did not notice anything amiss.

On Sunday, October 10, the evening after the conjunction, Johann Brunowsky saw a star, as bright as Jupiter, to the right of Jupiter, and above it about as much as Mars was below it. As he watched, in wonder, clouds came to blot out the view. In the morning he reported to Kepler what he saw. Not until October 17 was the sky cloudless at Prague. Meanwhile the new star was seen by various astronomers in various places. On the evening of October

[1] *Kepleri opera omnia*, vol. II, p. 617.

17 Kepler was watching at sunset. Before Jupiter was visible the Nova shone forth. From that moment it became Kepler's Star. He diligently observed it. On November 16 he saw it for the last time that year. The sun was approaching. On January 3, 1605, it was visible as a morning star, but not quite as bright as it was. Thereafter its brightness declined. In the year 1605 Kepler last saw it on October 8; already, because of its diminished brightness, the sun was too close for the star to be seen in the evening sky. In January and February 1606 Kepler was looking for it in the mornings, but it was never seen again with the naked eye. To Kepler it was *Nova Stella in Pede Serpentarii,*—the New Star in the foot of the Serpentholder; to-day it is known as the variable *Nova Nr. 1 (1604) Ophiuchi,*—and, at its brightest, ranks as the second brightest Nova recorded in history. For October 17, 1604, Kepler gives the longitude (with reference to the first point of the sign Sagittarius) and latitude (with reference to the ecliptic) of the planets and the Nova as follows:

	Long.		Lat.				Long.		Lat.		
Saturn	11°	39′	1°	26′	N.	Jupiter	20°	35′	0°	13′	N.
Nova	17°	40′	1°	56′	N.	Mars	25°	17½′	1°	36′	S.

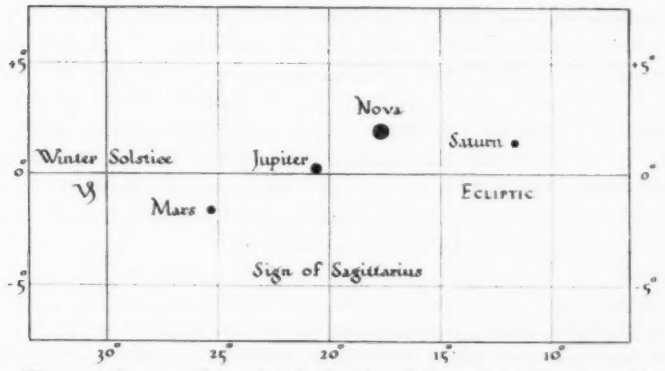

Diagram of a part of the sign Sagittarius of the zodiac, with the positions of Mars, Jupiter, Saturn and Kepler's Nova on October 17, 1604.

Whilst the Nova was in the sky Kepler was compiling material for a book about it. This book was published in Prague in 1606. It

was entitled *De Stella Nova in Pede Serpentarii.* It is printed in *Kepleri opera omnia,* II, pp. 611-750. Whilst thinking much about his star and his book, Kepler went down to Gratz, in Styria, on some business connected with his wife's property. There he came across a book which set him thinking about the Star of Bethlehem. "When last summer", he wrote to Johann Barwitz, on September 6, 1606, "I went to Styria, about family affairs, a piece of good luck befell my studies, for I found for sale at Gratz a small book of Laurence Suslyga of Poland, entitled: *Theoremata de anno ortus ac mortis Domini, deque universa Jesu Christi in carne oeconomia.*[2] Wonderfully pleased with the argument of this book, I began to think of accommodating it to my little book on the New Star in the Serpentholder, which I was then contemplating. For, if the author was correct, in order to reckon the Age of Christ, four years must be added to the Epoch of Christianity now in use. It would follow, therefore, that Christ was born one or two years after the great conjunction of the three Superior Planets in the first part of *Aries* or in the end of *Pisces,* occurring for the sixth time since the foundation of the world.[3] Hence, the star which led the Magi to the manger of Christ, if it occurred two years before the birth of Christ, could be compared with our star." (*Kepleri opera omnia,* IV, p. 177.)

Before Kepler could make comparisons he had to establish that Christ was born two years after the beginning of the great conjunction. With this end in view he added an appendix to his *De Stella Nova in Serpentarii.* In it he rehearsed the arguments of Suslyga. He pointed out that five complete years before our era led to 31 December B.C.6. or 1 January B.C.5. He placed the death of Herod a year earlier than did Suslyga; this enabled him to reach the year 5 B.C. as the year of the coming of the Magi.

[2]The title page of the book to which Kepler refers was, in fact, inscribed: *Verificatio seu Theoremata de anno ortus et mortis Domini, deque de universa Jesu Christi in Carne Oeconomia, quae ad Bacculaureatus in sacra theologia lauream in Alma Grecensi Academia in disputationem adducit Reverendus Dominus et eruditus Artium liberalium ac Philosophiae Magister Laurentius Suslyga Polonus. Praeside R.P. Joanne Deckerio Societatis Jesu SS. theologiae Doctore, ac dictae Universitatis Cancellario . . . . Graecii . . . . 1605".*

[3]Kepler supposed that the "great conjunction" occurred a little less than every 800 years, starting with the yeat 4,000 B.C.

Kepler's excursion into the field of chronology laid him open to criticism from many sides. He was unflinching in the defence of his position. And, as regards the Star of Bethlehem, he always had the same suggestion to make. His definitive work on the date of the birth of Christ was *De Vero Anno quo Aeternus Dei Filius Humanam in Utero Benedictae Virginis Mariae Assumsit,* (Frankfort, 1614). In this book, when he comes to consider the Star of the Magi, he says: "This star was not of the ordinary run of comets or new stars, but by a special miracle moved in the lower layer of the atmosphere"[4] And then he goes on to tell how the conjunction of the planets might have been a harbinger of the miraculous star: "The Magi were of Chaldea, where was born astrology, of which this is a dictum: Great conjunctions of planets in cardinal points, especially in the equinoctial points of Aries and Libra, signify a universal change of affairs; and a cometary star appearing at the same time tells of the rise of a king. . . . Granted, then, that the new star of the Magi was first seen not only at the same time as Saturn and Jupiter were beheld each in the other's vicinity, namely in June B.C.7, but also in the same part of the sky as the planets . . . . what else could the Chaldeans conclude from their, and the still existing, rules of their art [of astrology], but that some event of the greatest moment was imminent? . . . Nor do I doubt but that God would have condescended to cater to the credulity of the Chaldeans". (*Kepleri opera omnia,* IV, p. 347).

Kepler calculated that Jupiter appeared to pass Saturn three times in the year B.C.7, namely in June, August and December, when they were in *Pisces.* He calculated that there was an apparent conjunction of Mars with Saturn, in *Pisces,* in February B.C.6, and with Jupiter, in *Aries,* in March B.C.6. He pointed out that the sun was close on the heels of Mars. He held that Christ was conceived about the time that the major planets were in conjunction with the sun; that the Magi arrived in Jerusalem in February B.C.5, to see for the second time (Matthew, II.9-10) the star which they had seen for the first time (Matthew, II.2) in B.C.7.

[4] "Stella haec non fuit e numero communium cometarum aut novorum siderum, sed accessit illi privatim miraculum motus in inferiori regionis aëris". (*Kepleri opera omnia,* vol. IV, p. 346).

Who was the first to suppose that the Star of Bethlehem might have been nothing more than a conjunction of planets? We get some light on this question in Ludwig Ideler's *Handbuch der mathematischen und technischen Chronologie,* (2 vols., Berlin, 1825-26). According to Ideler (II, p. 406), Schubert of Petersburg wrote in his *Vermischten Schriften* in 1823: "A learned prelate of the Lutheran Church, Bishop Münter, was the first to conceive the happy idea that the great star which the Wise Men from the East followed to Bethlehem, was perhaps nothing else but the remarkable conjunction of Jupiter and Saturn." To the remark that Bishop Münter was the first, Ideler puts a footnote: "We see that this is a mistake". The only evidence for its being a mistake is Ideler's *ipse dixit* (II, p. 400) that Kepler held the same. *We* see that this is a mistake. The prevalence of the error that Kepler held the Star of Magi to be nothing but planets close together, is fundamentally due to Ideler. His *Handbuch,* which ran to a second edition in 1883, is much quoted; Kepler's works are little read. That Ideler had some idea as to what Kepler really held is suggested by his closing words on the subject: "That an extraordinary star of the kind seen in *Ophiucus,* or a comet, also arrived there [where the planets were], is an hypothesis which in my opinion we need not even once call to our aid." (II, p. 408).

It was in 1821 that Dr. Münter, bishop of Zealand, (Denmark), suggested that the Star of Bethlehem might have been a conjunction of the two planets Jupiter and Saturn. He also suggested that astronomers "draw up an exact reckoning of the conjunctions occurring about the time of the birth of Christ" (Ideler, *Handbuch,* II, p. 406). Ideler undertook the task. Kepler had made his calculations from the Prutenic Tables (*Kepleri opera omnia,* IV, p. 347); Ideler used Delambre's tables. He calculated that Jupiter appeared to pass above Saturn in B.C.7 three times, namely May 20, October 27, and November 12. He calculated that at each conjunction "the difference of latitude amounted to only one degree, so that for a weak eye the one planet almost passed over into the circle of dispersion of the other, so that both could seem to be but a single star" (II, p. 407). Here it may be asked: Had the Magi weak eyes? Would Wise Men ever

mistake two planets for a single star? And it may be remarked that those who lived in unilluminated towns or villages watched the wandering of the planets and saw them advance and retrograde, approach and separate; that those who crossed the desert were not unfamiliar with the stars,—the only "life" there was for them to watch at night.

On June 13, 1856, C. Pritchard read a paper before the Royal Astronomical Society on the conjunctions of Jupiter and Saturn; in it he reported: "I undertook the computation of the geocentric places of the two planets for the year B.C.7, so far as any possible conjunctions were concerned; and the result is, that so far as the fact of there having been three conjunctions during the year, Dr. Ideler's statement is confirmed; but the dates in that year to which he has assigned them are not correct. Still less is it true that any such proximity occurred as to make it possible that the planets could, to any observer, have presented the appearance of a single star. . . . I ventured to request the Astronomer Royal to permit the verification of my results to be made at Greenwich. To this request he most kindly and promptly acceded; and I had the gratification of finding my results fully confirmed . . . both sets of calculation assign very early in the morning of Dec. 4, B.C.7, as the time of actual conjunction. The difference of geocentric latitude was 1° 2′ 40″ sexagesimal; and the tables made use of were Carline's for the sun, and Bouvard's for the planets, with a correction for the mass of *Jupiter*. The great inequality was necessarily calculated from Laplace's formula, since the tables do not reach to so remote a period. From the result of the computation it follows that to no eyes, however weak, could the planets have appeared to be diffused into one; . . . . On the contrary, the planets never appeared during that year to have approached each other within double the apparent diameter of the moon" (*Memoirs of The Royal Astronomical Society*, XXV, pp. 120-121).

Kepler's calculation that the conjunction of Jupiter with Saturn took place on the night of December 3, 7 B.C., in 17° of Pisces (*i.e.* in longtitude 347°) agrees very well with Pritchard's calculation that it took place very early in the morning of December 4, in longitude (to the nearest degree) 346°. Pritchard does not even consider the approach of Mars to Jupiter and Saturn in February and March

B.C.6., since neither Ideler nor Kepler had suggested that these three planets could be mistaken for a single star, for, in Ideler's words: "at about this time Jupiter and Saturn lost themselves in the rays of the evening sun" (*Handbuch*, II, p. 408). Pritchard gives the places of Saturn in B.C.7, as follows:

May	29	350°	59′	43″
Sept.	29	347°	32′	20″
Dec.	4	345°	33′	44″

the first two being for Paris mean midnight, and the third for Paris 6 P.M. mean time. The sun, at the same time, on December 4, was in longitude 250° 57′ 58″. From these values I deduce that by February 12, B.C.6, the sun would be within 24° of Saturn. Mars was then closer to the sun, but moving towards Saturn. This means that from about the middle of February, Saturn and Mars would be too close to the sun to be seen by the naked eye.[5] Hence the statement that Mars, Jupiter and Saturn formed a triangle in the sky about February 25, B.C.6 (*Science News Letter*, December 19, 1936, p. 393) is misleading, inasmuch as the triangle could not be seen. When Saturn reappeared, at the end of March, as a morning star, Mars and Jupiter were not visible. When all three were objects of the morning sky, they had moved apart considerably.

The answers to the questions which this paper set out to consider would seem to be:

1. Kepler wrote about the star of Bethlehem to compare it with his Nova of 1604, which appeared the day after a conjunction of Mars with Jupiter and was last seen two years later.

2. Kepler suggested that the Star of Bethlehem was first seen by the Magi at the time of an apparent conjunction, of Jupiter and Saturn,—which he assigned to June 22, B.C.7, and which Pritchard calculated to have occurred on May 29, B.C.7. Kepler further suggested that the Chaldeans had heard of a star that was to rise to herald a Messiah-king in Judea. The appearance of the star in 7 B.C.

[5]From November 16, 1604 to January 3, 1605 Kepler could not see his Nova which was brighter than Saturn. The Nova was in longitude 257° 40′, and the sun, on November 16, in longitude 233°, and on January 3, in longitude 282°.

at the beginning of a series of conjunctions (not all seen, but known by calculation to occur) would have great meaning for the astrologically minded. According to Kepler's chronology the Star of the Magi was seen for the second time from Jerusalem about February, B.C.5.

3. That the Star of Bethlehem might have been nothing more than the conjunction of planets, seems to have been first suggested by Bishop Münter in 1821.

4. Ideler, in 1826, attributed Münter's hypothesis to Kepler.

5. No matter how close together two planets come,—even if one planet should be so close to another as to occult it partly,—Wise Men would not mistake them for a single star. A few nights' watching would show them separating,—as, also, they would have been seen to come together. In 7 B.C. Saturn and Jupiter were as close as twice the diameter of the moon. In 6 B.C., towards the end of February, Saturn, Mars and Jupiter formed a triangle in the sky; but Saturn and Mars, at least, were too close to the Sun to be seen by naked eye observers.

Jesuit Seminary of Philosophy,
Toronto, Oct. 22, 1937.

MEETING OF THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS

By D. W. Rosebrugh

THE Twenty-sixth Annual Meeting was held at Harvard College Observatory, Cambridge, Mass., on October 15, 16 and 17, through the kind invitation of the Director, Dr. Harlow Shapley. Some 80 members and friends from Wisconsin, Illinois, Michigan, Ohio, New Jersey, New York and New England, and several Canadians now resident in the States were present.

On Friday evening the Bond Astronomical Club acted as host to the members of the A.A.V.S.O. Dr. Charles H. Smiley of the Ladd Observatory, Providence, R.I., described his trip to Peru in June, 1937, where he photographed the solar eclipse with an F1 Schmidt camera. The exposure of 60 seconds appeared to show the inner portions of the zodiacal light as well as the greatly over-exposed corona.

The business session of the Association was held on Saturday at 10 p.m. Dr. Dirk Brouwer of Yale, chairman of the Occultation Committee, presented a fine annual report. In commenting upon this work Dr. Ernest W. Brown pointed out that in observing lunar occulations one is really checking the rate of rotation of the earth and he predicted that this will soon alter, for the earth's cumulative change in rotation period has now surpassed all previous maxima.

Mr. L. E. Armfield, Milwaukee, First Vice-President, reported that the Nova Search programme is being carried on systematically though no one has found a nova or a comet yet.

The Pickering Memorial Astronomer, Mr. Leon Campbell, Recorder of the A.A.V.S.O., reported that 53,358 observations upon variable stars were made by 166 members during the previous twelve months, so that the total observations made to date by the members exceed 600,000. Some 1500 light-curves of variable stars have been drawn up for a study regarding possible changes in the amplitude of the variations in the brightness of the stars.

Mr. Chas. W. Elmer, New York, was elected President to succeed Dr. Shapley, Mrs. Helen S. Hogg of the David Dunlap Observatory was elected Second Vice-President and Mr. D. W. Rosebrugh succeeded Mr. Elmer as Secretary.

The members were entertained at luncheon by Dr. and Mrs. Shapley and thus had a chance to talk with old friends and to form new.

In the afternoon a number of papers were presented by amateurs. Mr. Roy A. Seely, New York, formerly of Montreal, told of his "richest field reflector" with a 4-inch mirror of 15½ inches focal length. With a 1-inch eyepiece this telescope has a field of about 3° and can be held in the lap when one sits on a chair observing variable stars. Mr. Rosebrugh told of his series of observations on the brightness of the asteroid Vesta during the winter of 1937. These gave some slight indication of a period of axial rotation of 0.85 days.

The fourth Merit Award of the Association was presented to Mr. Eugene H. Jones of Goffstown, N.H., who has made 34,000 observations since 1920.

At the annual dinner in the Harvard Faculty Club, Dr. Eric M. Lindsay, newly appointed Director of Armagh Observatory, Ireland, as successor to the 'patron saint of telescope makers', the late Rev. W. F. A. Ellison, described tht Bloemfontein Observatory of Harvard, which is a twin of that at Oak Ridge, Mass. Dr. Shapley acted as toast-master and interspersed between the talks of the speakers a rapid fire inventory of the latest scientific discoveries.

Several motor cars filled with members visited the Oak Ridge Observatory on Sunday morning, and were shown the 61-inch reflector and the seismograph by Drs. Dimitroff and L. Don Leet of Harvard.

Poughkeepsie, N.Y.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Congratulations

To Dr. Ralph E. DeLury, of the Dominion Observatory, Ottawa, President of the Royal Astronomical Society of Canada, who is the recipient of one of the medals struck in honour of the Coronation of King George and Queen Elizabeth.

Plaskett's Sketch of Ambrose Swasey

In our November issue (at p. 403) was a notice of the death of Ambrose Swasey, together with some of his recorded sayings as given by Professor J. J. Nassau. In the present number we are pleased to print a fuller account of the life of this distinguished man, written by Dr. J. S. Plaskett, who, since retiring from the Dominion Astrophysical Observatory, has been appointed scientific consultant to the firm of Warner & Swasey.

Rutherford Buried in Westminster Abbey

All who realize the value of science to the world and who have any knowledge of the outstanding work done by the late Lord Rutherford will be pleased to learn that, following a service in Westminster Abbey on October 25, he was buried there in the "Science Corner" beside Newton, Faraday, Darwin and Kelvin.

Annual Meeting of the A.A.V.S.O.

We are pleased to print in this issue a short account of the recent annual meeting of the American Association of Variable Star Observers, and to learn that interest in this work is growing in Canada. More amateurs are urged to undertake this useful branch of astronomy, which does not require expensive equipment. They will find it interesting and will be associated with an enthusiastic and stimulating company of observers. Full information may be obtained from D. W. Rosebrugh who, by the way, is the son of an honoured professor and a graduate of the University of Toronto.

SONNET TO ALBERT EINSTEIN

The author of the following poem has courteously supplied the text for publication here.

ALBERT EINSTEIN

When first your thesis' thunderbolt was hurled,
Sending its challenge to the farthest skies,
You shook the basis of Great Newton's world
And lessened Euclid to a finite size.
Thus many a doubting Thomas held his praise,
Until the Sun itself came to your succor,
Fading in dark eclipse to show that rays
From nearby stars curved round its shadowed border.
And Mercury, too, did play his helpful part,
Since with his shifting orbit, which had never
Answered to any law which men could chart,
He clinched the proof to end all doubt forever.
Then Light itself to give its aid was led,
And moved its solar spectrum to the red.

Oconomowac, Wis. *Alex. B. Uhrig.*

SIR WILLIAM HERSCHEL

Recently I have been dipping again into "The Herschel Chronicle" which for some time has been on a shelf beside half a dozen other volumes dealing with the great astronomer and his devoted sister. It was prepared by Constance A. Lubbock, granddaughter of William Herschel, and contains numerous details, arranged with excellent judgment and skill, which were not available before its publication.

When in England I have twice visited the beautiful city of Bath and have gazed with interest on Herschel's house at 19 New King St., in the garden behind which he discovered the planet Uranus (1781); on what used to be the Octagon Chapel where he was organist; and also on the famous Pump Room where his concerts were held and where one may still sip the evil-smelling and ill-tasting mineral water.

The Octagon Chapel was built in 1770 and is described as the first of the proprietary chapels which became a special feature of the famous health resort. "The invalids and fashionable visitors who crowded to Bath shrank from the gloom and chill of the Abbey Church; in these chapels they could listen to their favourite preach-

ers and hear good music in comfort without the disagreeable presence of the common people." During January, 1771, the *Bath Chronicle* carried in several issues the following advertisement:

As this Chapel is private property and consequently no Persons can with any reason expect that the Sexton should open the pews to them unless they have taken seats, this public Notice is given that all Strangers who come to Bath for the Seasons may have what sittings they please, for one, two, or three months, in the Recesses (where six Fires are kept for the sake of Invalids) or any other part of the Chapel, by applying to Mr. Bulman, the clerk, at Mr. Herschell's in the New King Street, or at the Vestry, an hour before Service, on Sundays, Wednesdays, and Fridays.

Herschel was married in 1788, at the age of fifty, to the widow of a neighbour at Slough, and a son, who became the famous Sir John, was born March 9, 1792. Among Herschel's friends and admirers was Dr. Charles Burney, a distinguished musician, the author of a well-known history of music, and the father of the famous literary lady Madame d'Arblay or Fanny Burney. On the death of his wife he undertook to write a history of astronomy in verse in order to distract his mind from his sorrow. Burney had often been invited to Herschel's home at Slough, and in a letter written in September, 1797, he gives this pleasing picture of the Herschel family:

. . . I went thence to Dr. Herschel, with whom I had arranged a meeting by letter, but being, through a mistake, before my time, I stopped at the door to make inquiry whether my visit would be the least inconvenient to Herschel that night or next morning. The good soul was at dinner but came to the carriage himself to press me to alight immediately and partake of his family repast; and this he did so heartily that I could not resist.

I was introduced to the company at table; four ladies and a little boy about the age and size of Martin. I was quite shocked at intruding upon so many females. I knew not that Dr. Herschel was married and expected only to have found his sister. One of these females was a very old lady, and mother, I believe, of Mrs. Herschel, who sat at the head of the table. Another was a daughter of Dr. Wilson, an eminent astronomer of Glasgow; the fourth was Miss Herschel. I apologized for coming at so uncouth an hour, by telling my story of missing Lord Chesterfield through a blunder, at which they were all so cruel as to join in rejoicing. . . . We soon grew acquainted, I mean the ladies and I; for Herschel I have known very many years; and before dinner was over all seemed old friends just met after a long absence. Mrs. Herschel is sensible, good-humoured, unpretending, and obliging; the Scots lady sensible and harmless; the little boy entertaining, comical, and promising. Herschel, you know, and everybody

knows, is one of the most pleasing and well-bred natural characters of the present age, as well as the greatest astronomer. . . . We two therefore walked and talked over my subject round his great telescope, till it grew damp and dusk, and then we retreated into his study to philosophize. I had a string of questions ready to ask, and astronomical difficulties to solve, which, with looking at curious books and instruments, filled up the time charmingly till tea. After which we retired again to the study, where, having now paved the way, we began to enter more fully into my poetical plan, and he pressed me to read to him what I had done. Lord, help his head! he little thought I had eight books or cantos, of from 400 to 800 lines, which to read through would require two or three days!. . . .

I began therefore my eighth chapter. He gave me the greatest encouragement, repeatedly saying that I perfectly understood what I was writing about; and he only stopped me in two places, one was at a word too strong for what I had to describe, and the other one too weak. The doctrine he allowed to be quite orthodox concerning gravitation, refraction, optics, comets, distances, revolutions, etc., etc., but he made a discovery to me which, had I known sooner, would have overset me, and prevented my reading to him any part of my work! this was that he had almost always had an aversion to poetry, which he had generally regarded as an arrangement of fine words without any adherence to truth; but he presently added that when truth and science were united to these fine words, he then liked poetry very well.

Dr. Burney had several more opportunities of reading to his friend. Indeed Herschel arranged to visit Chelsea for another reading and under date December 10, 1798, Burney says:

"He came and his good wife accompanied him; and I read four books and a half. . . . And on parting, still more humble than before, or still more amiable, he thanked me for the instruction and entertainment I had given him! What say you to that?. . . .

On the first evening Herschel spent at Chelsea, when I called for my Argand lamp, Herschel, who had not seen one of those lamps, was surprised at the great effusion of light; and immediately calculated the difference between that and a single candle and found it as Sixteen to one."

In the end Burney destroyed his manuscripts but we can thank him for giving us this charming picture of his distinguished friend.

An Ever Recurring Story

Some fifteen years ago the present writer heard the following story.

On one occasion Sir Walter Raleigh, the Oxford professor, was arriving in New York to fill an engagement in the United States. One who was to be his host was at the dock to meet him, but he had never seen him. On accosting a person walking down the

gang plank with, "Are you Sir Walter Raleigh?" the quick reply was, "No, I'm Christopher Columbus". Now it would appear that this is one of the most ancient of jokes. E. T. Bell in his most interesting work, "Men of Mathematics", has the following (p. 137):

> Many legends and anecdotes have grown up round the famous Bernoullis, as is only natural in the case of a family as gifted and as violent in their language as the Bernoullis sometimes were. One of these ripe old chestnuts may be retailed again as it is one of the comparatively early authentic instances of a story which must be at least as old as ancient Egypt, and of which we daily see variants pinned onto all sorts of prominent characters from Einstein down. Once when travelling as a young man Daniel modestly introduced himself to an interesting stranger with whom he had been conversing: "I am Daniel Bernoulli". "And I", said the other sarcastically, "am Isaac Newton". This delighted Daniel to the end of his days as the sincerest tribute he had ever received.

C. A. C.

October Report of the Variable Star and Nova Search Observing Section—Toronto Centre

This observing section boasts of two very enthusiastic members. Mr. Neil McNabb made good use of the few clear nights available in October to make 21 searches for novae. He now identifies the stars in six regions down to the seventh magnitude. He also made four magnitude estimates of three variables. Mr. Bert Topham distinguished himself by making 11 magnitude estimates, nine of these in one night for nine different variables. The same night he searched 3 regions for novae, identifying all the stars down to the eighth magnitude.

F.S.P.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Visual Observations of the Perseids in 1937

As mentioned previously in these columns, poor weather conditions in Ontario considerably hampered efficient Perseid observation in 1937. The first night for which observations were planned was completely overcast at all stations. On the second night, Aug. 11-12, there were short periods of clear weather at most points. On Aug. 12-13 occasional clouds appeared for the first few hours of darkness but the last half of the night was generally clear, and on the following night, Aug. 13-14, the weather conditions were perfect. Mr. John Middlebrook again organized a group of observers from the London Centre, and Miss Burland and Mr. Thomson conducted observations in and near Ottawa as on previous occasions. The detailed account of the Ottawa observations will be found later in this report. Mr. Murray Speirs took charge of a group observing at a boys' camp near Torrance, on Lake Muskoka. Miss Northcott organized an active group at the artists' summer school in Port Hope and observations were received from several other poins int Ontario. The writer was assisted in the observations at the Dunlap Observatory on all three nights by Mr. D. A. MacRae. No reports were received from the Montreal Centre this year owing to cloudy weather on the nights scheduled for observing. Though fewer meteors were seen than in previous years the interest of the shower was greatly enhanced by the appearance of two unusually bright meteors in the early morning hours of Aug. 13 and 14 respectively. These meteors were well observed and train drifts plotted at both Orillia and the Dunlap Observatory.

The personnel of the various groups fortunate enough to secure results is listed below. This list in no way indicates the total number of observers who were ready to help since completely overcast skies at the beginning of the first three nights of observation rather disorganized plans for co-operation between various stations.

THE PERSONNEL OF THE OBSERVING GROUPS

1. *David Dunlap Observatory:* A. H. Armstrong, D. A. MacRae, Miss M. McKinley, D. W. R. McKinley, P. M. Millman, W. F. Sirman.

2. 2a. *Ottawa and Hull:* Miss M. Burland, M. M. Thomson, Karl Buckthought, Miss Lena Ellichuck, Miss Dora Jolly, Miss Gladys Jolly, Stanley Mott, Sam Palef.

3. *Dwight, Ont.:* Mrs. R. M. Millman, R. N. Millman.

4. *Port Hope, Ont.:* Miss R. J. Northcott, L. Amos, F. A. Flock, Miss Jean Haeffler, Miss Alice Innes, Miss E. N. Jackson, Miss Helen Manning, R. Whiteley, J. B. Wilson.

5. *Torrance, Ont.:* J. M. Speirs, Wm. Brager, Murray Enkin, H. Ingraham, Wm. Lehrle, Perry Teale, Gordon Yearsley.

6. *Acton, Ont.:* Neil McNabb, Jr., F. Van Wyck.

7. *London, Ont.:* John Middlebrook, Major E. H. Anundson, Miss Pat Anundson, T. C. Benson, M. Connor, Prof. H. R. Kingston, Mrs. J. C. Higgins, J. C. Higgins, Dr. G. R. Magee, Mrs. L. G. Planques, L. G. Planques, Dennis Valentine.

8. *Georgian Bay, Ont.:* John Wickware.

9. *Lake Rosseau, Ont.:* C. J. Hunt.

10. *Orillia, Ont.:* Jack Grant.

11. *St. Thomas, Ont.:* O. Kilburn.

12. *Victoria, B.C.:* Dr. W. E. Harper.

A summary of all the visual observations received is given in table I. The number of meteors observed refers, in every case, to the group total, that is the actual number of meteors seen from any one station, no duplicates being included. Hourly rates, reduced to six observers in the usual way, are plotted in figure 1. In spite of frequent clouds or fog on Aug. 11-12 the intervals between cloudy spells were quite clear at most stations and so a fairly good idea of rates on this night has been obtained. As will be noted there was no marked difference in Perseid rate between Aug. 11-12 and 12-13. The two high rates obtained on these nights were by parties where little or no plotting was done and they are not thus in disagreement with the other stations. On the third night the Perseid rate definitely dropped on the average but an unexpectedly large number of meteors was seen for a short time at Port Hope. As in previous years the tendency of the Perseids to appear in groups of two or three close together was marked, especially at Dwight where no plotting was carried out. A detailed discussion of this feature of the Perseid swarm will be given at a future date. The magnitude

TABLE I

VISUAL OBSERVATIONS OF THE PERSEIDS, 1937

Date	Group No.	Aver. No. Observers	Observing Period (standard time)	Total Minutes Observed	Meteors Observed P	Meteors Observed NP	Remarks
Aug. 11–12	1	2	11.50– 3.05	150	54	10	cloudy at intervals
	3	1	11.45– 3.00	195	110	* 20	misty at end
	4	6	11.10– 3.25	255	155	38	occasional fog
	6	1	9.35–12.30	100	1	‡ 0	partly cloudy
	7	8	10.10– 2.50	200	38	15	haze and clouds
	8	1	9.50–11.00	70	6	‡ 2	
	9	1	10.30–12.50	140	44	6	
	10	1	10.45– 2.00		5	‡ 2	observed at intervals
	11	1	12.20– 2.15		9	1	haze and clouds
	12	1	11.13–11.58	45	32*		mist near horizon
Aug. 12–13	1	3	10.40– 4.10	330	205	44	generally clear
	2	2	12.50– 1.35	45	10	† 11	intermittent clouds
	2a	2	12.40– 1.30	50	14	† 4	intermittent clouds
	4	1	11.05–12.10	65	18	6	clear
	5	3	9.40– 1.40	200	140†		clouds 10.30-11.10
	6	1	10.35–12.00	85	4	‡ 0	haze at end
	10	1	12.40– 1.30		2	‡ 1	observed at intervals
	11	1	11.10– 1.50	160	34	6	
Aug. 13–14	1	2	11.40– 4.00	260	77	23	clear
	2	2	11.30– 3.30	240	58	† 44	clear
	2a	2	11.40– 3.30	230	70	† 30	clear
	4	3	11.55– 2.20	145	104	24	clear
	10	1	10.30– 4.20	91	31	† 18	clear
Aug. 14–15	10	1	11.40–12.20		1	‡ 1	haze and clouds
Aug. 15–16	10	1	12.50– 3.40	61	11	‡ 13	clear

*No plotting.
†Only 0 mag. and brighter plotted.
‡Only 0 mag. and brighter recorded.

Total meteors observed, 1,552.

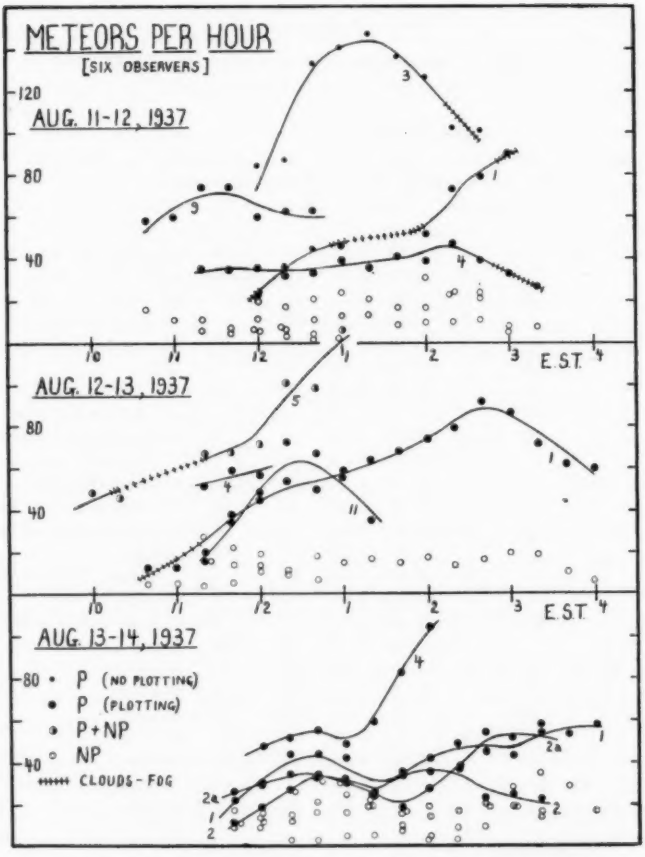

Fig. 1.—The hourly rates for Perseids (P) and Non-Perseids (NP). Each dot represents the reduced hourly rate for the complete hour centered at the plotted position. The numbers near the curves refer to the observing groups.

distributions for the stations where all meteors seen were recorded will be found in table II.

On comparing the 1937 Perseid rates with the three previous years, and taking the phases of the moon into account, it is evident that considerably fewer Perseids appeared in 1937 than in 1936. The Canadian observations of the Perseids made over the last four years would indicate approximately equal numbers in 1934 and 1935, fewer in 1936, and still fewer in 1937.

TABLE II

MAGNITUDE DISTRIBUTION OF PERSEIDS, 1937

	−5	−4	−3	−2	−1	0	1	2	3	4	5	Totals	Mean Mag.
Perseids													
D.D.O.	1	1		4	19	53	74	75	59	16		302	1.42
Ottawa and Hull			1	6	10	20	22	36	33	16	2	146	1.66
Others	1		3	13	16	47	137	183	158	102	36	696	2.17
Non-Perseids													
D.D.O.				1	5	7	6	21	12	3		55	1.62
Ottawa and Hull				1		6	11	20	20	18	7	83	2.72
Others			1	1	3	6	15	33	44	25	8	136	2.53

PERSEID OBSERVATIONS BY THE OTTAWA CENTRE AUGUST, 1937.

By M. M. Thomson and Miriam S. Burland

Observations of the 1937 Perseids were made by the Ottawa Centre from two locations: 1. The Dominion Observatory, with Miss Burland in charge; 2. The Department of Agriculture Research Station, Hull, Quebec, with Mr. Thomson in charge. Each group watched only half the sky, thus avoiding the necessity of looking over the city lights of Ottawa and Hull.

The equipment was similar to that of the previous year. At the Dominion Observatory, one camera was focused in the general direction of the David Dunlap Observatory, while at Hull two cameras, one with a prism and one with a rotating shutter, were directed towards the radiant. Each of the three cameras used $2\frac{1}{4}$ by $3\frac{1}{4}$-in. film and was equipped with an F/4.5 lens. The observers are indebted to the following people: Dr. E. A. Watson, chief patholo-

gist, for permission to use the Hull location; Mr. Wm. Hill, optometrist, for the use of a 30° prism; and Mr. R. Meldrum Stewart, director of the Dominion Observatory, for his help and guidance in the computation of results.

Weather conditions here, as with other locations, proved to be most disappointing, providing only one good night, Friday, August 13-14. An attempt was made on Aug. 12-13, but clouds finally closed over. Several volunteers with previous experience were thus unable to do any observing. Those who assisted in the observations were: Misses Lena Ellichuck, Dora Jolly, Gladys Jolly, and Messrs. Stanley Mott, Sam Palef, and Karl Buckthought.

On the one clear night, Aug. 13-14, a total of 202 meteors was recorded, two observers and one recorder being stationed at both Ottawa and Hull. The Hull group, looking towards the radiant, recorded a slightly greater proportion of Perseids, and the average magnitude estimate was a magnitude brighter than that of the Ottawa group. The results also indicate that the shower was definitely in progress even though this was not a night of maximum.

Only one meteor trail was recorded photographically, and that was with the camera located at the Dominion Observatory and directed towards the David Dunlap Observatory. It was also recorded visually by Miss Burland, who estimated its magnitude to be about −2. On the plate it appears in the constellation of Sagittarius, and its trail may be seen to cross the trails of πSag, oSag and the planet Jupiter. The measuring procedure followed was the same as that of last year, using π, o, and ξ Sag as the reference stars, and the points of intersection of the meteor and πSag and oSag. These two points proved to be as follows:

πSag and meteor	$19^h\ 07^m$	R.A.,	$-21°\ 7'$ Decl.
oSag " "	19 05	"	−21 51 "

This means that as seen from Ottawa, the directions were:

πSag and meteor	35° 25′ W. of S.,	15° 34′ above horizon
oSag " "	35° 31′ W. of S.,	14° 42′ " "

Considering the three cameras, the result of the photographic observation is one meteor for approximately eleven hours of exposure time.

Dominion Observatory,
Ottawa.

PHOTOGRAPHIC OBSERVATIONS OF THE PERSEIDS IN 1937

Photographic exposures were made at eight stations during the Perseid programme and one meteor spectrum was taken in 42 hours of exposure time, while eleven direct Perseid photographs were obtained in a total exposure time of 80 hours. The results of the photographic programmes at the Dominion Observatory and at the Dunlap Observatory have already been described. Mr. Grant, in Orillia, made exposures on five nights and secured three direct

TABLE III

PHOTOGRAPHIC OBSERVATIONS OF THE PERSEIDS, 1937

Date	Station	Total Exposure	Meteors Photographed	Camera Speeds
	Spectrophotography			
Aug. 11–12	Dunlap Obs.	7.1 hrs.	.	F/4.5, F/4.5, F/4.5
12–13	Dunlap Obs.	17.8	1	
13–14	Dunlap Obs.	14.2	.	
13–14	Hull	3.4	.	F/4.5
	Direct Photographhy			
Aug. 11–12	Dunlap Obs.	4.0 hrs.	.	F/5.6, F/3.8, F/4.5
11–12	Orillia	14 2	1	F/1.9, F/6.3, F/8
11–12	London	1.0	.	
11–12	Georgian Bay	1.2	.	
12–13	Dunlap Obs.	10.9	5	F/2.0, F/3.8, F/4.5, F/5.6
12–13	Orillia	15.6	2	F/1.9, F/6.3, F/8
12–13	St. Thomas	1.4	2	F/4.5
12–13	Acton	0.8	.	F/6.3
13–14	Dunlap Obs.	4.7	.	F/2.0
13–14	Ottawa	4.1	1	F/4.5
13–14	Hull	3.4	.	F/4.5
13–14	Orillia	12.8	.	F/1.9, F/6.3, F/8
14–15	Orillia	1.7	.	
15–16	Orillia	4.6	.	

photographs. Mr. Kilburn and Mr. Hobden at St. Thomas obtained two. Poor weather and dew greatly curtailed the photographic work at other stations. The co-ordination between the various stations, however, was even more gratifying than the total number of meteors photograped, as one meteor was recorded at three points and two more were photograped at two points. This material, together with the observations of train drifts from both Orillia and Richmond Hill for the two brightest meteors, should provide some very valuable results. The complete study of the Perseid photographs will appear in the Publications of the David Dunlap Observatory at a future date. The summary of the exposures at the various stations will be found in table III.

Thanks are due to all those who so ably assisted in both the visual and photographic work and it is to be hoped that the interest in amateur meteor photography, which produced such good results this year, will continue to increase in the future.

P. M. M.

REVIEW OF PUBLICATIONS

The Distribution of the Stars in Space, by Bart J. Bok. Pp. 124, 9½ x 6½ ins. Chicago, University of Chicago Press, 1937. Price $2.50.

This is the first of a series of Monographs, published by the publishers of the *Astrophysical Journal*. It is based on part of a series of lectures which Professor Bok, of Harvard University, gave at the Yerkes Observatory.

If the stars were all of the same absolute magnitude, and the galazy were free from absorbing matter, the space structure of the galaxy could be determined in detail from a series of star counts to various magnitudes, over the whole sky. In the actual galaxy the stars differ widely in absolute luminosity, and the apparent luminosities are seriously affected, both by general absorbing matter and by definite dark nebulosities. This monograph discusses the analysis of star counts in order to determine the structural features of our galactic system, taking into account these difficulties.

The book is divided into three chapters, dealing with Methods of Analysis, Data of Observation, and Problems of Galactic Structure. In the first chapter the author shows how star counts may be used for examination both of random distribution and of departures therefrom. Then follows an outline of the equations by which the space density of the stars may be determined from an observed series of star counts, using an assumed luminosity function. The luminosity function, and the analytical and numerical methods of finding the space distribution are discussed, together with methods of locating absorbing nebulosity from star counts.

The second chapter deals with the actual observational data contained in various catalogues, and the conclusions that have been reached as to distribution and dark nebulosity in various star fields.

The last chapter considers various specific problems, including distributions perpendicular to the galactic plane, the local star cloud, star clouds in general, and the indications of spiral structure in our galaxy.

The book is well planned and serves as an excellent survey of current work in this important subject. It is, of course, technical rather than popular, and presupposes a working knowledge of mathematics. This book is printed in the same familiar pleasing form as the *Astrophysical Journal*. It is unfortunate that so important a monograph should be published in paper binding. As an extended series of these brief monographs is planned the price per volume is such as to make the probable total cost of the set very high. F. S. H.

The Prediction and Reduction of Occulations, supplement to the Nautical Almanac for 1938. 46 pp. H. M. Stationery Office, London, 1937. 2/ net.

Of recent years increasing importance is being attached to the observation of occultations and to the use of these observations particularly to determine the errors of the tables of the motion of the moon and, consequently, the irregularities in the earth's rotation period. The observations are carried out at many observatories and by more serious amateurs. The immediate observational results are merely the identification of the occulted star, the place of observation and the times (preferably to within a fraction of a second) of disappearance and/or reappearance.

Prerequisite to a program of observation of occultations is a list of predicted occultations with approximate times. Such lists are published in the Nautical Almanac, American Ephemeris and elsewhere for all portions of the globe where observations are published in various publications, forming a valuable collection of data to be used as indicated above. Ultimately, of course, it is necessary that each observation be reduced by elimination of the place of observation so as to obtain the errors in the orbital latitude and longitude of the moon as given by the tables. Elements for carrying out these reductions are given in the Nautical Almanac.

The Prediction and Reduction of Occultations describes in detail the methods used by the Nautical Almanac Office for computing the predictions and reducing the observations. Observers of occultations will find the booklet of considerable interest and usefulness; and, in particular, the hope is expressed that it will encourage observers to reduce their own observations before publication. J. F. H.

MEETINGS OF THE SOCIETY

AT VICTORIA

October 6, 1937.—The first meeting of the fall series was called to order at 8.10 p.m. by President Shaw. The President informed the society of the acquisition to the library "The Five Halley Lectures" presented to the Centre by Dr. J. S. Plaskett.

The following members were elected: Mr. W. E. Beart, Mr. E. L. Bott, Mr. R. H. Dellar, Mr. O. Kockoff, Mr. A. Swaluk, Mr. G. Irvine (Junior), Miss D. P. Humeston (Junior), Mr. P. E. Olsen (Junior).

The report of the summer essay competition committee was read by Mr. H. B. Brydon. The prize for the best essay was awarded to Mr. Thomas Pepper, at present studying at the University of B.C.

The President then called upon the speaker of the evening, Dr. J. S. Plaskett, who addressed the Centre on "Special Features of the new 200-in. and 82-in. Telescopes". The lecturer introduced his subject with a brief sketch of the career of George Ellery Hale, founder of the Kenwood, Yerkes and Mt. Wilson Observatories, whose influence was of the greatest importance in the securing of support for the project of building the 200-inch telescope. In passing, Dr. Plaskett paid great tribute to the vision and energy of Dr. Hale in prosecuting such important astrophysical aims.

Using numerous lantern slides, the speaker described first the site and then the casting of the mirror, and the construction of the mounting for the mammoth 200-inch telescope. New and significant features of design were noted, the polar ring and oil-supporting-system deserving special mention as well as the new method of driving telescopes by means of synchronous motors. The 200-inch telescope will reach distant objects 1,000,000,000 light-years away and will greatly extend our knowledge of extra galactic objects. In order to collect and focus the light the mirror surfaces require one ounce of aluminum; in order to mount and drive these surfaces, the mounting requires one million pounds of steel.

Following this, Dr. Plaskett gave a brief résumé of the 82-inch telescope, now in an advanced state of construction for the MacDonald Observatory in Texas. The audience were greatly interested in the details of these two great telescopes and concurred heartily in the vote of thanks proposed by Mr. K. O. Wright.

Following this lecture the Vice-President, Mr. R. Peters, gave a brief talk on sun-spots and other interesting celestial phenomena, now visible. Some excellent drawings of recent sun-spots by Mr. Brydon were exhibited.

October 27, 1937.—The meeting was called to order by President Shaw at 8.10 p.m. The following were elected to membership in the Society: Mr. W. Rose, Miss Mary Flanagan (Jr.), and Miss Margaret Gravlin (Jr.).

The Vice-President Mr. Robert Peters gave a short talk, mentioning the

conjunction of Jupiter and Mars and the approaching lunar eclipse. Using the Great Square of Pegasus he described its individual stars and showed how one could proceed from this square to identify many constellations and objects of interest. The appearances of Saturn and Uranus, now well-situated for observations were described. Following this Mr. Peters gave the report on the summer course competition in sketching constellations. The prize, donated by a member of the society, was a copy of Norton's "Star Atlas" and was awarded to Miss D. P. Humeston, honourable mention being given to Mr. A. H. Young and Mr. Gerald Irvine.

The President then called upon Miss Phoebe Riddle to deliver the lecture of the evening upon the subject, "How the Earth Moves". The speaker introduced her topic by a discussion of motion and inertia, utilizing Newton's first law to emphasize the fact that uniform motion is a natural and ordinary thing. Following this came a discussion of the geocentric outlook of the middle ages culminating in the Ptolemaic model of the solar system and finally overthrown by the labours of Copernicus, Tycho Brahe and Kepler. A brief sketch of the life of the last-named was given and then the lecturer proceeded to describe the principal motions of our planet. These are:

(1) Revolution around the sun; (2) Rotation upon an axis; (3) Precession of the Equinoxes; (4) Nutation; (5) Variation in terrestial pole; (6) Changes in shape, inclination and orientation of orbit; (7) Solar Motion; (8) Galactic Motion Effects.

The results of these various movements were described and illustrated by means of lantern slides.

R. M. PETRIE, *Secretary.*

AT TORONTO

October 26, 1937.—The regular meeting of the Toronto Centre was held in the MacLennan Laboratory, University of Toronto, on Tuesday, October 26, Mr. E. J. A. Kennedy presided.

The following were elected to membership in the Toronto Centre: Mr. Kenneth Baines, 614 Mount Pleasant Rd., Toronto; Miss Margaret Burt, 651 Spadina Ave., Toronto; Mr. Mort Farrington, 15 George St., Weston; Mrs. Geo. Holledge, Kapuskasing, Ontario; Mr. Ted Morris, 198 Ellis Ave., Swansea.

Mr. Duncalfe brought to the attention of the members the conjunction of Mars and Jupiter on Friday, October 29, and graphically explained the meaning of the term conjunction.

The speaker of the evening was Dr. Kingston of the University of Western Ontario. His subject was "The Way of the Moon". Dr. Kingston pointed out the necessity for distinguishing between apparent and real motions in the sky. It is to be noted that the apparent motion of the sky and the real motion of the moon are in opposite directions, and that the apparent motion of the sun and the real motion of the earth are in the same direction. From a map of the equatorial region, on which are shown the ecliptic and the moon's path, it is seen that the moon moves close to the apparent path of the sun among the stars but about 13 times more rapidly. This fact of the moon doing in a month what the

sun does in a year and a knowledge of the phases of the moon enable us to predict how the moon will ride the sky at any phase at any time of year.

Dr. Ainslie, formerly of the University of Western Ontario, moved a hearty vote of thanks to Dr. Kingston for his most interesting and instructive lecture.

The first of a series of short lectures on the elements of Astronomy was delivered by Dr. J. F. Heard of the David Dunlap Observatory. This lecture dealt with the celestial sphere and the different co-ordinate systems used by astronomers in designating the position of an object in the sky.

November 9, 1937.—The regular meeting was held in the McLennan Laboratory, Mr. E. J. A. Kennedy in the chair.

The following were elected to membership in the Toronto Centre: Mr. Charles G. Ellis, 399 Dupont St., Apt. 2, Toronto; Mr. J. J. Noad, 115 Lawrence Cres., Toronto; Mr. George H. Tidy, 21 Kenneth Ave., Toronto; Mr. Herbert W. Wilkins, 19 Wolverleigh Blvd., Toronto.

The speaker of the evening, Dr. C. A. Chant, Director Emeritus of the David Dunlap Observatory, gave a very fine account of the advance of knowledge in his lecture, "The Motions of the Stars".

Dr. Chant pointed out that the term "fixed stars" is not referred to as often as it was in former days. It is now realized that the stars are actually in motion and that this term is really not suitable. The motions of the stars can be divided into two parts, transverse and radial. Halley, in 1718, was first to observe the transverse component. He found that his observed positions of Arcturus and Sirius differed from those recorded by Ptolemy. The determination of proper motions is now often done by a stereoscopic comparison of photographs.

Motion in the line of sight is measured by the Doppler Principle. Doppler attempted in 1842 to explain the colour of double stars from a shift of the spectrum due to the motion of each star. He failed to realize the existence of infra-red and ultra-violet radiation. Some six years later Fizeau pointed out that the spectral lines would shift due to the motion of the star, and so developed the Fizeau-Doppler Principle as it is now used.

Dr. Chant pointed out that it was not until after the invention of the dry plate that measurable results were obtained. The determination of the radial velocities of stars is now a routine business at large observatories.

This Fizeau-Doppler principle has also been applied to the spectra of extra-galactic nebulae. The results show that the larger the velocity the smaller is the object. This decrease in apparent size has been interpreted as an increase in distance. One of the chief reasons for the building of the 200-inch telescope is to determine the speed, and hence the distance of these faint objects.

A brief discussion followed the lecture.

The second lecture by Dr. Heard dealt with time. It was pointed out that sidereal time is really the simplest method of reckoning time, and that our standard time is quite complicated.

RUTH J. NORTHCOTT, for *Recorder*.

RADIO TALKS OVER CFCT, VICTORIA, B.C.

By W. E. Harper

Jupiter's Markings

(August 7 1937)

On a former occasion (see this Journal for January, 1930) I used my allotted time on the air in giving the main facts about Jupiter, the largest of the planetary bodies. We learned that it moved about the sun in 11.86 years at an average distance from the sun 5.2 times that of our earth. Though 1300 times the size of the earth it turns much more rapidly on its axis, making one complete rotation in 9h 55m. Brief reference was made to its surface markings, the so-called equatorial belts, but the physical conditions upon the planet were not dealt with at any length.

In the course of another radio talk upon "Planetary Atmospheres" (see this Journal for February, 1936) remarks were made regarding the presence of ammonia and methane gas in the atmosphere of Jupiter. It is my purpose now to elaborate still further upon recent discoveries as to physical conditions in its atmosphere. The subject is a timely one inasmuch as Jupiter is now the most conspicuous planet in the sky, rising as it does in the south-east in the early evening. It is too far south to be conveniently observed with the 72-inch reflecting telescope, but it is one of the objects shown through a small telescope to our numerous Saturday night visitors.

Let us recall what one can learn about Jupiter through the use of a telescope. While it is often stated that the four moons discovered by Galileo can be seen with an ordinary opera glass one must have steady hands to do so. The other five moons are too faint to be seen with an ordinary telescope. If the seeing is good and you can steady the opera or field-glass you will see, in addition to these four moons, narrow bands or streaks crossing the planet's surface. These are the so-called equatorial belts and they are parallel to the line joining the moons. These belts vary in number, width and position from year to year and they are coloured, reds and browns predominating.

Unless you have a telescope of about six inches aperture or greater that is about all you can hope to see. With one from six to nine inches in diameter, however, you may expect to see finer markings and will be able to follow these across the disk as the planet rotates. Most of these markings are short-lived, lasting a few weeks at most, there are others of a semi-permanent nature. Of such a character is the great red spot, first noted in 1878 and afterwards traced

back on photographs and drawings to 1831. It is roughly elliptical in form, the longer axis being 30,000 miles and the shorter 7,000 miles. At discovery it was of a brick-red colour and it has from time to time undergone changes. It is still recognized as an apparent hollow in the edge of the great southern belt and as such it appeared on drawings of nearly 100 years ago. Whatever it is, it is not permanently attached to the nucleus below as it does not maintain a constant rate of rotation nor does it remain definitely in the same latitude. It floats in a fluid medium, or in other words, it is atmospheric.

Not only does its colour change but that of the belts does as well. In these colour observations, which are carried on by many amateur astronomers, as well as a few professionals—there are difficulties besetting one's pathway. If the planet is far south its altitude in the sky will never be very great and atmospheric dispersion will create fictitious colouring effects. The upper or (with us) the northern edge will be blue and the southern red and possibly some of the conflicting colours reported have been the result of failing to allow for such atmospheric dispersion. When precautions have been taken, however, it is found that the colours of the north and south polar regions are the same and that there is a real change in the colours of the equatorial belts from year to year.

From the reports of those engaged in observing Jupiter under the direction of the British Astronomical Association, it would appear that in 1936 the belts were not quite as red as this so-called red spot. One of the outstanding workers, A. Stanley Williams, states that the red spot was very red and plainer in 1936 than in any year since 1883.

Moreover, as intimated just now, the colouring of the belts in the two hemispheres seems to undergo a cyclic change, those in the north being redder some years and then yielding the palm to those of the southern hemisphere. The period of variation of colour has been estimated differently by different workers but the most recent by Williams makes it coincide almost exactly with the period of revolution of the planet about the sun. If this be true the colour effects might be seasonal in character, analogous to that which an outside observer would see taking place on our earth. In the winter he would see the northern hemisphere, white with snow and half a year later green would be the predominating colour, with white for the southern hemisphere. There is this objection, though, that we are relatively close to the sun as compared with Jupiter and the variations of temperature and consequent changes as between winter and summer would be much less marked on Jupiter than with us. Moreover the inclination of Jupiter's equator to its orbit about the sun is only 3°, whereas that of the earth is 23½°, so that on this score also there should be very little seasonal effect and this is the view taken by Slipher of the Lowell Observatory. Nevertheless, Williams ascribes the colour changes to this cause and gave the epoch 1933.40 when the south equatorial belt had its maximum redness and the north belt was least red. At the epoch 1939.33 conditions should be reversed and the north belt should then have its maximum redness.

If the period of approximately twelve years in which the colours of the equatorial belts pass through their cyclical changes be real then there is the

possibility of some connection with the sun-spot cycle, for its period is also between eleven and twelve years. However this implied relationship seems very far-fetched and while it has been suggested in print, I do not think it is entertained seriously by anyone.

Jupiter's Atmosphere

(September 21, 1937)

Last month I discussed the changes in colour which are observed in the belts on Jupiter's surface. They seemed to be seasonal in character, passing through a cycle in about the same time as the planet takes to move about the sun, namely 11.86 years. There is, however, considerable uncertainty about the reality of these colour changes and the question will be settled only after a series of photographs, taken through coloured screens, has been made throughout the entire cycle of 11.86 years. The difficulties from atmospheric dispersion will of course be present in these, as in the visual observations, but proper choice of an observing site will help. Plates are now available for use in every region of the spectrum from the ultra-violet to the infra-red and a long-continued series of photographs using emulsions sensitive to different colours will yield the desired information.

Not only will such negatives yield data on the colour of the belts but they will also tell us if there are changes in the form of the planet itself. It is well known that the planet is not spherical for it shows an elliptical disc in a small telescope, the flattening in the polar direction being of the order of seven per cent. When we recall that it has such an extensive atmosphere and that it rotates so rapidly that a point on its equator is swirled nearly 500 miles in a minute, we can readily believe that it would bulge out at the equator. Photographs in light of different colours reveal striking differences. The photographic images made on emulsions sensitive to ultra-violet light are larger and show a much greater bulging than those made with infra-red light. This greater oblateness of the ultra-violet images shows that the material thus photographed is at a higher level in the atmosphere than that whose presence is recorded by the infra-red plates.

The rapid changes of the surface markings make it almost certain that they are clouds of some sort. Their rapid motions and transformations suggest a vigorous circulation in the planet's atmosphere, with rapid exchange of material between the surface and the underlying depths. Such might suggest that the core or nucleus of the planet is hot and convection currents are carrying the heated material up from below. This was the view held until recently but now it is believed that there is little internal heat and that all it has it receives from the sun. This finds corroboration in the fact that the satellites of Jupiter, when they pass into the shadow cone cast by the sun, are completely invisible. Were there any appreciable surface heat from internal sources the darkened hemisphere of the planet should glow sufficiently to illuminate the satellites faintly, but such is not the case.

Jupiter being 5.2 times as far from the sun as our earth, it will receive, area by area, only 1/27 of the heat received by us. Moreover, its surface is highly

reflective and throws off 60 per cent. of the light incident upon it. With these data, calculation can be made of the probable temperature of its surface and it is found to be more than a hundred degrees below zero on the Centigrade scale. This theoretical result has been checked by observation, using a delicate form of electrical thermometer known as a radiometer, and the mean of the results gives a temperature of −140°C. At this temperature, of course, clouds of water vapour, as we know them on the earth, could not exist and the question arises as to the nature of the constituent gases which can apparently "boil" at this low temperature.

It is here that the spectroscope comes to our aid. The analysis of the light from Jupiter showed that its spectrum was much like that of the sun, which was just what we would expect if it shone wholly by reflected sunlight. Moreover, the spectrum of the bright equator was nearly the same as that of the cloud belts. There did not seem to be any great difference between the two. There were, however, certain strong absorption bands peculiar to the common spectrum which it was felt must have their origin in the planet's atmosphere. No similar bands had been found in the laboratory in the spectra of the ordinary elements. These bands were however well marked in the spectra of Saturn, Uranus and Neptune. As they increased in strength from Jupiter to Neptune it was thought that there was some correlation with distance from the sun. However, after Pluto was discovered this idea had to be given up as no such bands appeared in its spectrum.

Now, while these bands were noticeable in the region of spectrum ordinarily photographed they become much stronger in the red region. With the newly discovered dyes which gave us emulsions sensitive to red light Slipher about 1907 found strong Jovian bands in the region λ 7200 to λ 7265. In 1932 new dyes were available which made possible the photography of the spectrum up to and beyond λ 10,000 and increasing strength of these absorption bands was found to be the rule. If such absorption continued beyond the infra-red the heat radiations would suffer in consequence. This seems to be the case on Jupiter, and increasingly so in the case of the other major planets, so that the low temperatures obtained from radiometric observations are readily understood. These observations of temperature naturally refer to the outer surface of the atmosphere or, as we might term it, the stratosphere of the planet. What conditions exist deep down in the atmosphere is another question.

The nature of the absorbing matter was discovered by a young German physicist, Wildt, in 1932. Certain gases like water-vapour and carbon dioxide have their strongest absorptions in the infra-red and only fainter ones in the more accessible part of the spectrum. For them to be recorded at all in the laboratory a long absorbing path is required. Utilizing observations of this sort Wildt showed that some of Jupiter's bands were due to ammonia, a compound of nitrogen and hydrogen, and others due to methane gas, accompanied by carbon and hydrogen. Later, with better equipment, Adel and Slipher, employing a 45-metre path of the gases under a pressure of 40 atmospheres so as to get a very long equivalent path, were able to identify practically all the bands. The amount of ammonia in Jupiter's atmosphere corresponds to 10 metres at our atmospheric pressure whilst that of methane corresponds to one mile at similar pressure.

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